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LIME-SULFUR AS A SUMMER SPRAY

Apples showing excessive scab.

By ERRETT WALLACE

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LIME-SULFUR AS A SUMMER SPRAY

General Results of Investigations During 1909-1910

Bordeaux mixture, which has been the standard fungicide for years, is well known to have one seriously objectionable effect, especially when used to control apple scab, in that under certain weather conditions it induces serious russeting of the fruit and sometimes causes foliage injury. This fact constitutes the main reason why we are looking for substitutes. Experiments by several investigators during the past three

FIG. 70.—*Power sprayer used at Sodus in the* 1910 *experiments.*

years have given promise that the objectionable features of bordeaux may be avoided and as good results obtained by substituting some form of lime-sulfur preparation.

During the seasons of 1909 and 1910, the writer has conducted experiments as a Fellow on the Niagara Sprayer Company Fellowship in the Department of Plant Pathology, under the general direction of Professor H. H. Whetzel. The work of 1909 was conducted on the farm of Mr. L. B. Frear of Ithaca, and continued on a more elaborate scale at Sodus, N. Y., in the orchards of B. J. Case, Henry Baxter, Daniel Legasee, Paulus Johnson and Mr. Green. Much credit is due to all of these men for the very liberal manner in which they co-operated in the work.

The present article consists only of a bare statement of some of the most practical conclusions drawn from these experiments, leaving practically all discussion for other publications which treat the various phases of the subject in detail. For a further and more technical discussion the reader is referred to bulletin 288 on *"Lime-Sulfur Injury,"* and to bulletin 290 on *"Studies of the Fungicidal Value of Lime-Sulfur Preparations."*

CONTROL OF THE APPLE SCAB

The following tables record the results of our principal experiments on the control of the apple scab during the seasons of 1909 and 1910. The times of applications are indicated with each fungicide by numbers, Ex. 1, 3, 4:

1 Just as color showed in blossom buds (Fig. 76).
2 Just as blossoms fell (Fig. 77).
3 Two weeks after blossoms fell (Fig. 78).
4 Nine weeks after blossoms fell.

TABLE 1.— RESULTS OF SPRAYING EXPERIMENTS ON GREENINGS IN THE FREAR ORCHARD DURING 1909.

TREATMENT	Sound %	Scabby %	Russeted %	Wormy %	Total number counted
Unsprayed	2.5	42.3	29.7	25.0	1,663
Bordeaux 3–4–50 + lead arsenate 3–50	9.9	3.0	82.2	3.3	2,332
Lime-sulfur (heavy grade) 1–30 + lead arsenate 3–50	52.0	3.6	3.7	1.5	2,632

NOTE.— In this case application No. 2 was the only effective one.

TABLE 2.— RESULTS OF SPRAYING EXPERIMENTS ON BALDWINS IN THE CASE ORCHARD DURING 1910.

TREATMENT	Sound %	Scabby %	Russeted %	Codling Moth %	Total number counted
Unsprayed	1.3	98.7	35.5	7.2	730
Bordeaux 3–3–50 + lead arsenate 2–50 (Nos. 1–2–3–4)	26.6	18.3	60.3	.8	2,687
Lime-sulfur (heavy grade) 1–30 + lead arsenate 2–50 (Nos. 1–2–3–4)	61.3	11.7	26.4	.5	2,902
Lime-sulfur (heavy grade) 1–30 + lime 4–50 (Nos. 1–2–3–4)	61.2	26.4	11.6	.8	1,423
Lime-sulfur (heavy grade) 1–30 + lead arsenate 2–50 + lime 4–50 (No. 2 only)	71.3	13.8	14.6	.3	877

FIG. 71.—*Greenings as they hung on the trees sprayed with bordeaux mixture and lead arsenate.*

FIG. 72.—*Greenings as they hung on the trees sprayed with lime-sulfur and lead arsenate.*

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TABLE 3.— RESULTS OF SPRAYING EXPERIMENTS ON BALDWINS IN THE LEGASEE ORCHARD DURING 1910.

TREATMENT	Sound %	Scabby %	Russeted %	Codling Moth %	Total number counted
Unsprayed	30.2	69.8	27.4	37.9	496
Bordeaux 3–3–50 +lead arsenate 2–50 (Nos. 1–2–3–4)	30.0	17.7	62.0	1.9	1,500
Lime-sulfur (clear) 1–30 +lead arsenate 2–50 (Nos. 2–3–4)	73.2	13.2	13.0	.5	1,531
Lime-sulfur (clear) 1–30 +lead arsenate (Nos. 1–2–3. No. 4 omitted)	65.2	22.0	12.6	1.9	1,685
Lime-sulfur (home-boiled) 20–15–50 (diluted equal 1–30) +lead arsenate 2–50 (Nos. 1–2–3–4)	58.2	16.1	23.3	2.4	1,373
Lime-sulfur (heavy grade) 1–30 +lead arsenate 2–50 (Nos. 1–2–3–4)	68.8	14.3	16.1	.6	2,235

TABLE 4.— RESULTS OF SPRAYING BALDWINS ON A COMMERCIAL SCALE. SPRAYED BY MR. CASE'S MEN.

TREATMENT	Sound %	Scabby %	Russeted %	Codling Moth %	Total number counted
Lime-sulfur 1–40 +lead arsenate 2–50 (Nos. 1–2–3–4)	62.3	17.8	19.3	.5	1,011

TABLE 5.— RESULTS OF SPRAYING EXPERIMENTS ON GREENINGS IN THE LEGASEE ORCHARD DURING 1910.

TREATMENT	Sound %	Scabby %	Russeted %	Codling moth %	Lesser apple worm %	Total number counted
Unsprayed	26.6	58.3	11.2	22.4	4.8	624
Bordeaux 3–3–50 +lead arsenate 2–50 (Nos. 1–2–3–4)	34.5	6.6	58.2	3.2	7.6	2,745
Lime-sulfur (clear) 1–30 +lead arsenate 2–50 (Nos. 1–2–3–4)	87.0	6.9	2.1	1.2	2.6	1,291
Lime-sulfur (heavy grade) 1–30 +lead arsenate 2–50 (Nos. 1–2–3–4)	82.9	12.9	1.4	1.05	1.7	3,135
Lime-sulfur (heavy grade) 1–30 +lead arsenate 2–50 (Nos. 1–2–3)	74.0	17.1	2.6	3.1	3.8	905

TABLE 5 — (Concluded).

TREATMENT	Sound %	Scabby %	Russeted %	Codling moth %	Lesser apple worm %	Total number counted
Lime-sulfur (heavy grade) 1–30 +lead arsenate 2–50 (Nos. 3–4)	34.4	58.9	4.2	11.5	5.8	926
Sediment of Niagara lime-sulfur 1–15 +lead arsenate 2–50 (Nos. 1–2–3–4)	83.0	13.1	1.3	.5	2.0	1,252
Lime-sulfur (home-boiled conc.) 1–30 + lead arsenate 2–50 (Nos. 1–2–3–4)	73.6	13.5	1.1	1.1	1.6	1,095
Lime-sulfur (home-boiled) made with excess of lime diluted to equal 1–30 +lead arsenate 2–50 (Nos. 1–2–3–4)	43.8	44.4	5.2	2.9	5.2	171

TABLE 6.— RESULTS OF SPRAYING EXPERIMENTS ON GREENINGS IN THE BAXTER ORCHARD DURING 1910.

TREATMENT	Sound %	Scabby %	Russeted %	Codling moth %	Lesser apple worm %	Total number counted
Unsprayed	.5	79.4	9.1	72.0	5.7	175
Bordeaux 3–3–50 +lead arsenate 2–50 (Nos. 1–2–3)	34.1	17.7	39.7	4.0	4.3	322
Lime-sulfur (clear) 1–30 +lead arsenate 2–50 (Nos. 1–2–3)	80.4	10.9	3.4	3.0	2.2	265
Lime-sulfur (clear) 1–40 +lead arsenate 2–50 (Nos. 1–2–3)	70.3	8.1	.0	14.9	6.7	74
Lime-sulfur (clear) 1–30 +lead arsenate 2–50 (No. 2 only)	65.0	18.1	4.4	11.0	1.3	226
Lime-sulfur (clear) 1–30 alone, no lead arsenate (Nos. 1–2–3)	23.7	29.5	6.9	58.2	.8	261
Lime-sulfur (clear) 1–30 +lead arsenate 2–50 pp't. with gas sprayer (Nos. 1–2–3)	75.5	7.7	5.4	8.0	3.3	334
Sediment of home-boiled lime-sulfur made with pure lime 2–30 +lead arsenate 2–50 (Nos. 1–2–3)	68.5	26.7	1.1	1.2	2.5	752
Magnesium oxid 10–50 +lead arsenate 2–50 +Resin sal soda sticker (Nos. 1–2–3)	54.5	39.9	1.8	1.9	1.9	782
Self-boiled lime-sulfur 10–10–50 +lead arsenate 2–50 (Nos. 1–2–3)	53.6	39.0	1.6	3.1	2.5	313
Self-boiled lime-sulfur 10–10–50 +lead arsenate 2–50 +iron sulfate 3–50 (Nos. 1–2–3)	62.6	33.0	1.4	2.4	.5	415

TABLE 7.— RESULTS OF SPRAYING EXPERIMENTS ON HUBBARDSTONS IN THE BAXTER ORCHARD DURING 1910.

TREATMENT	Sound %	Scabby %	Russeted %	Codling moth %	Lesser apple worm %	Total number counted
Unsprayed	.0	94.6	6.9	89.9	11.6	129
Lime-sulfur (clear) 1–40 +lead arsenate 2–50 (Nos. 1–2–3)	85.0	3.2	1.9	2.6	7.1	154
Lime-sulfur (clear) 1–30 +lead arsenate 2–50 (Nos. 1–2–3)	87.6	3.3	1.2	3.6	4.2	664
Lead arsenate (alone) 2–50 (Nos. 1–2–3)	66.8	29.4	1.1	.4	2.0	432
Magnesium oxid 10–50 +lead arsenate 2–50 + resin sal soda sticker (Nos. 1–2–3)	49.6	45.9	.9	1.1	2.3	518
Sediment of home-boiled lime-sulfur made with pure lime 2–30 (Nos. 1–2–3)	35.4	53.1	2.0	7.3	2.0	96
Self-boiled lime-sulfur 10–10–50 +lead arsenate 2–50 +iron sulfate 3–50	76.7	17.1	.0	4.3	1.8	275
Lime-sulfur (clear) 1–30 +lead arsenate 2–50 pp't. with gas sprayer (Nos. 1–2–3)	69.9	6.1	1.2	4.9	2.9	672

Below is taken up a brief consideration of the important points brought out by these experiments.

EFFICIENCY OF LIME-SULFUR SOLUTION AS COMPARED WITH BORDEAUX

As a result of our work and observations for the past two years, together with the results recorded by others, we are convinced that lime-sulfur solution properly used in combination with lead arsenate is as effective in controlling apple scab as bordeaux mixture. The investigation has included a dry and a wet season with good results in both cases.

In 1909, the season was dry. In our own experiments, scab was reduced from 42 per cent. to 3 per cent. with bordeaux and lead arsenate, and to 3.6 per cent. with lime-sulfur and lead arsenate. See Table 1. Tables 2–7 show that during 1910 in three different orchards experiments with home-boiled and commercial preparations of lime-sulfur diluted 1–30 and 1–40 (on the basis of a 32° Beaumé test) combined with lead arsenate, and bordeaux 3–3–50 combined with lead arsenate, were, on an average, about equally effective. The lime-sulfur was used successfully on Baldwins, Greenings, Ben Davis, Hubbardstons and Pound Sweets.

THE ADDITION OF LEAD ARSENATE TO THE LIME-SULFUR

The combination of lead arsenate with the lime-sulfur solution causes a chemical reaction, changing the composition of some of the lead arsenate and the lime-sulfur solution. It had been predicted by chemists that this reaction would reduce the fungicidal value of the lime-sulfur, the insecticidal value of the lead arsenate, and increase the burning properties of the spray.

Our experiments both in laboratory and field tests have proved beyond doubt that the addition of lead arsenate not only does not decrease the fungicidal value of lime-sulfur solution but rather increases it by about 50 per cent. In the laboratory, fungicidal tests on spore germination with summer spores (conidia) of the apple scab fungus were made. Lime-sulfur alone diluted 1–50 reduced germination from 50 per cent. to 12.5 per cent., while with 1–100 and lead arsenate added at the rate of 2 pounds to 50 gallons, it was reduced from 66 per cent. to 0 per cent.*

On the trees, apple scab was reduced from 79.4 per cent. to 29.5 per cent. by lime-sulfur 1–30 alone, and to 10.9 per cent. by the same concentration of lime-sulfur with lead arsenate added.

On pear trees, the pedicle infection, which in bad cases caused dropping of young buds and blossoms, was counted May 19th to get a line on the early infection. With lime-sulfur 1–40 alone, applications 1, 2, 3 reduced this early infection from 73 per cent. to 13 per cent. while the same concentration of lime-sulfur and *lead arsenate* reduced it to 6 per cent. with application No. 1 only. On June 2nd the plat given sprayings Nos. 1, 2, 3, using the lime-sulfur alone, showed 76 per cent. infection, while the unsprayed showed 100 per cent. infection; with application No. 1 only, using lime-sulfur and arsenate of lead, there was 11.7 per cent. of scab.

THE SEDIMENT IN LIME-SULFUR

The general opinion has been that the sediment or solid part of a heavy-grade lime-sulfur or of a home-boiled preparation is worthless. According to laboratory tests, sediment from heavy-grade Niagara lime-sulfur was shown to have about one-half as much fungicidal value as the solution, volume for volume. Accordingly, during 1910, Greening trees were sprayed with the sediment which had been filtered, washed, and diluted 2–30, i. e., half as dilute as the clear solution. Arsenate of lead was used with it. The scab was reduced from 58.3 per cent. to 13.1 per cent., which compares quite favorably with most plats sprayed with the solution, as shown in Table 5. Further studies indicated that the value

* For method used in making these tests, see Wallace, E., Blodgett, F. M., and Hesler, L. R., Studies of the Fungicidal Value of Lime-sulfur Preparations, N. Y. (Cornell) Agr. Exp. Sta. Bul. 290. 1911.

of the sediment may vary with the magnesium content of the lime used in preparing the solution. Magnesium oxid itself, according to laboratory tests, has considerable fungicidal value. Sediment from a home-boiled solution made with pure lime (CaO) was less effective in preventing spore germination than when 25 per cent. of magnesium oxid was added to the lime used, previous to boiling, as shown by the writer et al ('11).

Magnesium oxid alone, 10 pounds to 50 gallons, without any poison, reduced scab or "black spot" on early St. Johns peaches from 56.5 per cent. to 3.5 per cent. On apples, however, the magnesium oxid with lead arsenate did not control scab any more effectively than did the lead arsenate alone, and according to count (Tables 6 and 7) it was even less effective. We attribute the failure to control scab in this case to the very poor adhesive qualities of the magnesium oxid. Sediment from a preparation to which magnesium was added, however, so far as data are available seemed more effective on the trees than that from a preparation made with pure lime alone. Since only a few apples set on the trees sprayed with the magnesium sediment this experiment is not conclusive.

In concluding the discussion of magnesium and of sediment we wish to make it clear that we are not recommending the use of magnesium lime for the preparation of lime-sulfur solution nor, in general, the use of sediment. Even though it be demonstrated that magnesium under certain conditions may prevent fungus infection, it does not demonstrate the advisability of using magnesium lime in preparing the solution. There are several things to be considered in this regard. It would doubtless be somewhat wasteful if the sediment is to be discarded, since the magnesium, according to Van Slyke et al. ('09), does not, to any extent, go into solution, but remains in the sediment. If, then, the sediment is discarded, the magnesium is discarded with it. Again, since the magnesium does not go into solution, considerable more sediment will be formed when it is present in the lime used, and this may in some cases be rather objectionable. These authors also state (l. c. 410) that in cooking considerable hydrogen sulfid (H_2S) is formed when magnesium lime is used. This is unpleasant and unhealthy for workmen and also results in the loss of some sulfur.

All we can say at present is that according to laboratory and field tests which are not yet positively conclusive (extending over only a

('09) Van Slyke, L. L., Hedges, C. C., Bosworth, A. W., A Chemical Study of the Lime-sulfur Wash. N. Y. (Geneva) Agr. Exp. Sta. Bul. **319**: l.c. 410–411. 1909.
('11) Wallace, E., Blodgett, F. M., and Hesler, L. R., Studies of the Fungicidal Value of Lime-Sulfur Preparations. N. Y. (Cornell) Agr. Exp. Sta. Bul. **290**. 1911.

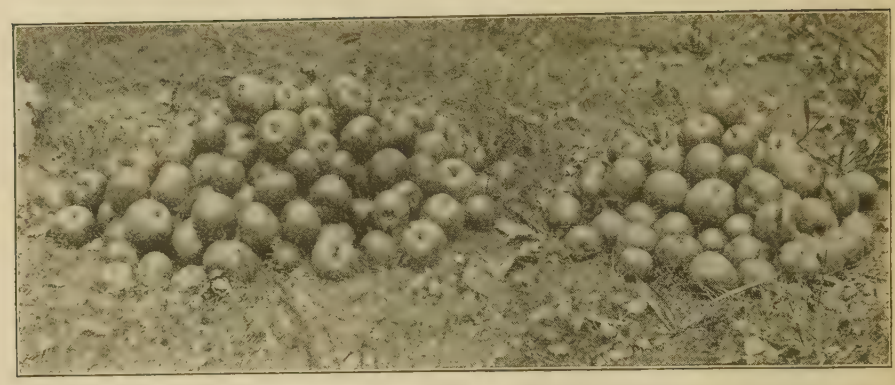

FIG. 73.—*Greenings from unsprayed trees. Scabby apples on the left.*

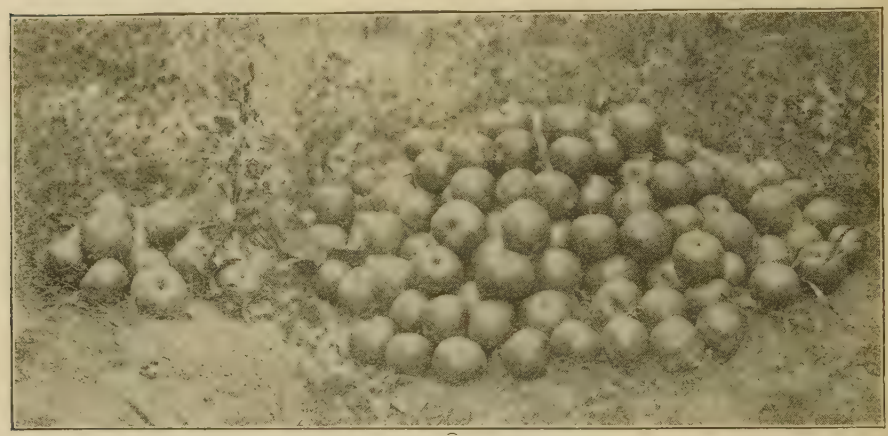

FIG. 74.—*Greenings from trees sprayed with lime-sulfur 1-30 and lead arsenate 2 lbs. to 50 gals. Scabby apples on the left.*

FIG. 75.—*Greenings from trees sprayed with sediment from commercial lime-sulfur (Niagara brand) 1-15, with 2 lbs. lead arsenate to 50 gals. Scabby apples on the left.*

single season), the presence of magnesium in the sediment increases its fungicidal value and that the sediment, especially from a solution made from lime high in magnesium content, is evidently worth using and should not be discarded as a worthless product. It is probable also that if the sediment is used with the solution, there is no loss of fungicidal value due to the use of magnesium lime since the magnesium would more than atone for the loss of the small amount of sulfur which it occasions. On the other hand, it is probably true that the greater inconvenience occasioned by the presence of magnesium in preparing the solution and necessity of handling a larger amount of sediment makes it desirable to use pure lime. As to whether the grower should purchase a commercial brand containing sediment is a question we do not attempt to answer. Our experiments for one season seem to show that the sediment from Niagara lime-sulfur has about one-half as much fungicidal value as the same volume of the solution. In Mr. Legasee's orchard, a test was made in comparing the heavy and the light grades. As shown in Table 5, there was somewhat more scab on the trees sprayed with the heavy grade. The difference was not great, and since the heavy grade in the other orchards compared as favorably with bordeaux as the light grade did in this, we are inclined to think that this variation may be within the range of experimental error. Since only one tree on this plat was counted, this is quite possible.

HOME-BOILED CONCENTRATED LIME-SULFUR

There is no reason why a home-boiled concentrated lime-sulfur should not be as safe and effective as the commercial if carefully prepared and diluted according to its strength. A row of trees in Mr. Legasee's orchard was sprayed with a home-boiled concentrate prepared according to the method of Van Slyke and Parrott ('09) and diluted to the same test as the commercial preparation. The control was practically equal in each case (see Table 5) and no difference as to foliage injury could be noted.

The directions for the preparation of home-boiled concentrate solution as given by Van Slyke and Parrott are as follows:

"For making the concentrated mixture the steps are the same as in making the usual boiled wash, but 60 pounds of lime and 125 pounds of sulfur are used for 50 gallons of solution. Slake the lime, make a thin paste, and add the sulfur. Flowers of sulfur or light or heavy sulfur flour may be used. The lime should be fresh lump lime, free from dirt and grit, containing 90 per cent. or more of calcium oxid and less than

('09) Van Slyke, L. L. and Parrott, P. J., Composition and Use of Lime-sulfur Washes. N. Y. (Geneva) Buls. 319 and 320 (Popular edition): l. c. 12. 1909.

5 per cent. of magnesium oxid. Stir thoroughly during the hour of cooking to break up the lumps of sulfur. Enough water should be added at the start so that evaporation will not leave the quantity less than 50 gallons when the cooking is ended. If kettles are used, 10 to 15 gallons additional will be needed, while with steam none may be required. The kettles should be considerably larger than the amount of wash to be made to prevent loss of material by boiling over. The clear liquid should be drawn off into tight containers if to be kept any considerable time and stored where there is no danger of temperature much below freezing."

FUNGICIDAL PROPERTIES OF LIME-SULFUR

From results of experiments recorded in Cornell Bulletin 290 we are convinced that the lime-sulfur solution as it goes on the tree does not act directly as the fungicide. In drying, relatively insoluble compounds are formed, among which is to be found the active agent. It is well known that carbonic acid gas as used in the gas sprayer destroys the soluble sulfur in a very short time, forming a fine, comparatively insoluble precipitate. This modification was expected to destroy the fungicidal value of the preparation. From our studies thus far, we have found it to be as efficient when precipitated as when applied in the soluble form. Table 6 shows this result to have been verified this season on apples where lime-sulfur and lead arsenate combined were applied in this way. On peaches, lime-sulfur diluted 1-30 alone applied in this way reduced the brown rot on Atlantas from 45 per cent. to 1.5 per cent. by two applications, and to 6.5 per cent. by one. The foliage was not injured. We know that a dilution several times weaker applied in the soluble form will cause serious injury if heavily applied to peach foliage. It is evident, therefore, that the *burning properties* lie in the *soluble sulfids* and that the *fungicidal properties* of the *lime-sulfur are not affected by precipitation.*

Lime-sulfur combined with lead arsenate, however, applied with the gas sprayer caused serious foliage injury on peaches, evidently resulting from the chemical action of the gas on the arsenical present in its changed form. On apples, this caused only slight injury in the case cited. Although, as stated above, this gave good control, we would not, in general, advise the use of the gas sprayer to apply lime-sulfur solution combined with lead arsenate even on apples until it had been further demonstrated that more serious burning under certain conditions might not result. On the other hand, if the grower already owns a gas sprayer and has only a few trees to spray, the probability is that results would be satisfactory if he used this machine, though we cannot guarantee it. In such a case, the agitator must be kept constantly in motion as the

precipitate settles very quickly and otherwise would be unevenly distributed.

SPRAY INJURY CAUSED BY LIME-SULFUR

Cornell Bulletin No. 288* consists entirely of a discussion of this phase of the subject, to which the reader is referred for more detailed information and for evidence on the conclusions herein presented.

In our experiments there seemed to be no correlation between the weather at the time of or after application and the resulting spray injury. In this, lime-sulfur injury differs from bordeaux injury, which is largely governed by weather conditions.

The method of application is a very important factor. Over-drenching is likely to cause burning of the foliage and should be avoided, at the same time taking care to thoroughly coat all parts of the tree.

Arsenate of lead is the only arsenical that has thus far proved to be safe for use with lime-sulfur solution on apple foliage. Arsenite of lime, arsenite of soda or paris green is likely to cause serious foliage injury, while lead arsenate to some extent reduces the caustic properties of lime-sulfur solution.

The addition of lime or the retention of sediment in the lime-sulfur solution seems to have very little effect on the amount of foliage injury caused by the spray. Precipitation of lime-sulfur solution alone, by carbon dioxid, as when applied with the gas sprayer, prevents its caustic action on peach foliage even when used as strong as 1-30. Precipitation of lime-sulfur and lead arsenate in the same way is very dangerous when used on peach foliage. The carbonic acid gas liberates soluble arsenic, which seems to be responsible for the burning.

Infection of apple leaves by the scab fungus previous to application, by injuring the leaf, admits the spray material more readily to the inner tissues and burning results. This is one of the most common causes of spray injury to foliage. Probably insect injuries also play an important part.

There is also some evidence that the foliage of healthy vigorous trees is better able to resist the caustic action of the spray material than that of weak ones. Just how far this is due to physiological conditions and how far to greater injury by parasites which naturally occur in uncared-for orchards is, as yet, uncertain.

Varietal susceptibility to injury is important, at least in case of pears. The Duchess is more susceptible than any other variety observed in our experiments. In apples, no marked degree of resistance or susceptibility

* Wallace, E., Lime-sulfur Injury. N. Y. (Cornell) Agr. Exp. Sta. Bul. 288. 1910.

has been noted on any varieties observed by us. Scott ('09), however, notes that the Winesap is more resistant to spray injury than other varities.

Russetting of apples by lime-sulfur is, at least, rare and of minor importance as compared with that caused by bordeaux. Considerable natural russeting occurred the past season (1910) on unsprayed trees, especially on Baldwins, caused by certain weather conditions. In our experiments there was in both seasons even less russeting on the lime-sulfur sprayed than on the unsprayed trees (Tables 1 and 5). We have not yet seen a clear case of russeting from lime-sulfur but such have been reported and we cannot dispute the possibility. Aside from the russeting, apples sprayed with lime-sulfur have invariably been more highly colored and had a finer, more waxy finish than those sprayed with bordeaux.

The action of lime-sulfur in causing injury differs fundamentally from that of bordeaux. Bordeaux injury may not occur for some time after the spray is applied, i.e., until atmospheric conditions are favorable. Lime-sulfur injury, we believe, is caused before the solution has dried on the tree. In other words, in bordeaux, as applied, the copper is in the insoluble (hydroxid) or harmless form and cannot cause injury until certain changes occur. In lime-sulfur solution, on the other hand, the sulfur is applied in the soluble (harmful) form, which is many times more caustic than at any time after it has once dried. It is probable that all cases of delayed or prolonged occurrence of injury from lime-sulfur combined with an arsenical are due to the arsenic and not to the lime-sulfur, as shown by the writer ('10) in Cornell bulletin 288 cited above.

TIME AND NUMBER OF APPLICATIONS NECESSARY

No specific directions can be given on this point. The time will vary with the season and the locality. Dates cannot be given. The best guide for the grower is to watch the development of the fruit buds and the weather. The first application should be given before the blossoms open, about as they begin to show pink (Fig. 76); the second, after the blossoms fall or when about two-thirds off (Fig. 77); and a third two weeks later (Fig. 78). Sometimes, if the late summer is very rainy or dews heavy, a fourth application may be necessary about eight or nine weeks after the blossoms fall to insure against late scab infection. Sometimes the poison is also necessary at this time to prevent the second brood of codling moth.

It is doubtless true that in many seasons a single application made just after the blossoms fall would give very good results. Even during the

('09) Scott, W. M., Lime-sulfur Mixtures for Summer Spraying of Orchards. U. S. D. A., Bu. Pl. Ind. Circ. 27: 1. c. 16. 1909.

FIG. 76.—*Time for first application for scab.*

FIG. 77.—*Time for second application for scab.*

past season (1910), which was very wet, this was true (see Table 2) in Mr. Case's orchard. In many instances, however, the omission of the spraying just before the blossoms opened permitted the scab on the pedicles to cause a serious dropping of the young forming fruit, resulting in a poor set and consequently in a light crop. This early fungous infection of the young fruit and pedicles was, we believe, the main cause of the generally light crop of apples throughout western New York this

FIG. 78.— *Time for third application for scab.*

season. This early infection also occurs on the leaves and is responsible for many mysterious cases of lime-sulfur injury. We therefore conclude that the first spraying before the blossoms open is chiefly instrumental in giving a better set when the early season favors scab infection, and in preventing foliage injury from later applications by keeping the fungus off of the leaves. The second application, after the blossoms fall, is usually the most important one in keeping the fruit free from scab. Most of the buds affected earlier than this seem to fall prematurely. The third application, two weeks later, seemed in our experiments to be of little importance during the seasons of 1909 and 1910. We would not dare to advise its omission as yet, however, since other seasons may give quite different results. There was some late scab infection the past season and on both Greenings and Baldwins the fourth application was of some service. (See Tables 3 and 5.) On Greenings there was 17 per. cent. of scab where the fourth application was omitted and 12.9 per cent. where it was given. On Baldwins, there was 22 per cent. where No. 4 was omitted and 13 per cent. and 14 per cent. where it was given.

DIRECTIONS FOR SPRAYING FOR APPLE SCAB WITH LIME-SULFUR SOLUTION

Application No. 1. Just before the blossoms open (Fig. 76). Lime-sulfur solution 33° Beaumé diluted 1–40 (2½–100) with 4 pounds arsenate of lead to 100 gallons.

Application No. 2. After blossoms fall (Fig. 77) or when about two-thirds off. Same as above. Make this spraying very thorough as it is usually the most important one of all.

Application No. 3. Two weeks later (Fig. 78). Same as above.

Application No. 4. About nine weeks after blossoms fall, as insurance against late scab infection and second brood of codling moth. Use same spray. In many seasons this is not needed.

In all cases, get the spray on before the rain if possible. Do not wait until the rain is over, fearing it will wash the spray off. If it has twenty minutes in which to dry, it will not easily wash off and it is during wet weather that the fungicide is needed to prevent fungous infection.

The dilution should be made according to the density of the concentrate as indicated by the Beaumé test. It is especially important that home-boiled solutions be tested since they vary greatly. The test must be made in the clear liquid, as the presence of sediment in it makes the Beaumé test unreliable.

Table 8 gives the number of dilutions for the various concentrates.

TABLE 8.— SHOWING THE CORRESPONDING NUMBER OF DILUTIONS OF LIME-SULFUR SOLUTION OF VARIOUS DENSITIES USING 32° BEAUMÉ AS A STANDARD.

°Beaumé	1–10	1–15	1–20	1–25	1–30	1–40	1–50	1–60	1–75	1–100
25°.....	7.4	11.0	14.7	18.4	22.1	29.5	36.8	44.2	55.0	73.
26°.....	7.7	11.6	15.4	19.3	23.2	30.9	38.6	46.3	58.0	77.2
27°.....	8.1	12.1	16.1	20.2	24.3	32.4	40.5	48.5	60.6	80.7
28°.....	8.4	12.7	16.9	21.1	25.4	33.8	42.3	50.7	63.5	84.5
29°.....	8.8	13.2	17.6	22.1	26.5	35.3	44.2	53.0	66.3	88.2
30°.....	9.2	13.9	18.4	23.0	27.6	36.9	46.1	55.3	69.0	92.0
31°.....	9.6	14.4	19.3	24.0	28.8	38.4	48.0	58.0	72.0	96.0
32°.....	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0	75.0	100.0
33°.....	10.4	15.6	20.8	26.0	31.2	41.5	52.0	62.4	78.0	104.0
34°.....	10.8	16.2	21.6	26.8	32.4	43.2	54.0	64.7	80.8	108.0
35°.....	11.2	16.8	22.4	28.0	33.4	44.9	56.0	67.4	84.2	112.0

NOTE.— The figures in the columns indicate the number of times the concentrate of a given density is to be diluted to give a dilution equivalent to that at top of column.

The method of application has much to do with results. If the spray be applied with a coarse nozzle and the operator holds it too long in one position, certain branches will be overdrenched and burning is likely to result. The coating of spray should consist of very fine drops evenly distributed over the entire surface. If the application is

too heavy, these drops coalesce to form large drops and dripping results. These large drops also collect at the tips and around the margins of the leaves and as they dry the solution becomes more concentrated and burns. The proper distribution of the spray can best be obtained by using high pressure and a nozzle with a small hole. Some operators may consider it necessary to use a coarse nozzle to control the codling moth, but we have had almost perfect results in this regard in using a fine spray with a high pressure. The number of nozzles that should be used on one rod will depend on the size of the holes, the condition of the orchard as to crowding of the trees, and the quickness of the operator. With too many nozzles in a crowded orchard where over-arching branches interfere with free motion of the rod, one is sure to over-spray certain branches. Better work can be done by spraying from both sides with the wind than by trying to spray both sides with the same wind. One should not, however, wait too long for favorable winds and miss getting the spray on at the right time, which is the most important factor in controlling the fungus.

Do not interpret what has been said to mean that spraying should be less thoroughly done. Most growers do not spray thoroughly enough. Care should be taken to coat all parts but not to over-drench any part of the tree. Remember that the spray protects only those buds, fruits, and leaves which are actually coated.

Finally, we would urge all to spray every year. The necessity for this is clearly shown by our experiments in Mr. Case's orchard. Here, in an orchard that had received the best of care and effective spraying for years, the omission of the spray for a single season gave 98.7 per cent. of scab. This is also evidence that we cannot by sanitary and cultural methods alone control apple scab. We must spray every year to insure clean fruit even in orchards receiving the most perfect care.

CONTROL OF PEACH ROT AND SCAB

The only method of controlling these diseases demonstrated to be safe, effective and practicable, is the self-boiled lime-sulfur treatment devised by W. M. Scott ('09) of Washington, D. C. Peach foliage is so extremely tender that lime-sulfur solution if used at all must be used very weak. A dilution of 1–100 when heavily applied caused quite serious burning in our experiments of 1909. Further tests that year gave some promise that even weaker solutions might be somewhat effective in preventing brown rot infection. Storage experiments also proved that peaches that had been sprayed with lime-sulfur 1–200 kept much better after being picked.

('09) Scott, W. M. Lime-sulphur Mixtures for the Summer Spraying of Orchards. U. S. D. A., Bu. Pl. Ind. Circ. 27:1–17. 1909.

In 1910, weak lime-sulfur solution 1–150 with arsenate of lead added was tried. No injury appeared until almost a month after the application. Then considerable burning occurred, evidently due to some change that had gradually taken place in the arsenical present.* From this, it would seem unsafe to use weak lime-sulfur solution and lead arsenate combined on peach foliage.

Further experiments along several lines have been conducted but since they have as yet led to no positive conclusions from the practical standpoint, we would at present simply refer the reader to the work of Scott cited above and point out the necessity for further experiments to determine the practicability and best methods for spraying peaches for rot and scab in New York State.

It might be further noted that in some cases brown rot and scab have been effectively controlled by lead arsenate alone. E. P. Taylor ('09), Entomologist of the Missouri Fruit Experiment Station, reports several such cases. He attributes the results to the control of the curculio, which is responsible for much rot infection by its punctures. It could not, however, account for the control of the scab and it is therefore evident that much of the benefit was due to the fungicidal value of the lead arsenate.

In this state, the brown rot is not so serious as in states further south although in some seasons it causes considerable loss. The scab, or black spot, however, is quite destructive on certain varieties, causing a considerable depreciation in the quality of the fruit, especially in wet seasons. Proper spraying would very effectively control this malady and would doubtless in many cases pay well for the work. Aside from controlling the fungi and curculio it is found that spraying gives a more highly colored fruit and that it prevents rot after picking, thus increasing its keeping qualities. In our experiments of 1909, Alexander peaches that had been sprayed three times with lime-sulfur solution 1–200, nine days after picking showed 12 per cent. of rot, while in the unsprayed there was 57 per cent. In 1910, Atlantas sprayed with lime-sulfur solution 1–30 precipitated with carbonic acid gas, after being kept four days gave only 17 per cent. of rot with 58 per cent. on the unsprayed. Scott and Ayres ('10) also note that peaches sprayed with self-boiled lime-sulfur reached the markets in better condition. These results indicate that properly sprayed fruit could be handled with much less loss than unsprayed, giving the grower more time to get it to market, the buyer more time to

*For details on this point, see N. Y. (Cornell) Bul. 288. 1910.

('09) Taylor, E. P. Spraying Peaches for Brown Rot. The Fruit Grower. Oct. 1909.

('10) Scott, W. M. and Ayres, W. T. The Control of Peach Brown-Rot and Scab. U. S. D. A., Bu. Pl. Ind. 174:20. 1910.

distribute and the consumer more time to consume it. This alone is an important point in the case of a perishable fruit like the peach. This, together with the improved quality and insurance against rot epidemics which occur in certain seasons, makes it highly desirable that summer spraying of peaches be more generally adopted in this state. One of the most pressing problems before us for another year is to work out the methods particularly adapted to our conditions. In the meantime, we are confident that two or three applications of the self-boiled solution combined with lead arsenate would give good results on varieties that are inclined to scab or rot.

For convenience, the directions given by Scott and Quaintance ('10) for preparing and applying this mixture are quoted:

"Self-boiled lime-sulphur mixture.— This mixture is composed of 8 pounds of fresh stone lime and 8 pounds of sulphur (either flowers or flour may be used) to 50 gallons of water. This appears to be about the correct strength, although in mild cases of scab and brown-rot a weaker mixture, containing 6 pounds of each ingredient to 50 gallons of water, may be used with satisfactory results. The mixtures can best be prepared in rather large quantities — say, enough for 200 gallons at a time, making the formula 32 pounds of lime and 32 pounds of sulphur to be cooked with a small quantity of water (8 or 10 gallons) and then diluted to 200 gallons.

"The lime should be placed in a barrel and enough water poured on to almost cover it. As soon as the lime begins to slake the sulphur should be added after first running it through a sieve to break up the lumps. The mixture should be constantly stirred and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

"The stage at which cold water should be poured on to stop the cooking varies with different limes. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot fifteen or twenty minutes after the slaking is completed, the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is

('10) Scott, W. M. and Quaintance, A. L. Control of the Brown-Rot and Plum Curculio on Peaches. U. S. D. A., Bu. Ent. Cir. 120:5–7. 1910.

therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely divided sulphur and lime, with only a very small percentage of the sulphur in solution. It should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through the strainer.

"Arsenate of lead.— Arsenate of lead comes on the market in a thick, putty-like paste, and must be worked free in water before addition to the lime-sulphur mixture. There are several brands upon the market and the grower should be careful to purchase from reliable firms. The addition of arsenate of lead to the self-boiled lime-sulphur mixture will bring about a decided change in color, but without injuriously affecting the value of the spray. Arsenate of lead is used at the rate of 2 pounds to each 50 gallons of water or lime-sulphur mixture.

"The amount of poison required for each spray tank of mixture may be weighed out into a bucket, thinned with water and poured through a strainer into the spray tank. In extensive operations, however, it is much more convenient to prepare a stock mixture in advance. Place 100 pounds of the material in a barrel with a bucket of water and work it into a thin paste with a spade or a large paddle, then dilute with water to make exactly 25 gallons. When thoroughly stirred, each gallon will contain 4 pounds of arsenate of lead, and the amount of poison for each spray tank of mixture may be measured, thus avoiding the trouble of weighing small lots.

SCHEDULE OF APPLICATIONS.

"For the Elberta, Belle, Reeves and other varieties of peaches of about the same ripening season, the following is advised:

"First application.— About the time the calyces, or shucks, are shedding from the young fruit, spray with arsenate of lead at the rate of 2 pounds to 50 gallons of self-boiled lime-sulphur mixture. Since this application is rather early for scab, and since serious outbreaks of brown-rot do not usually occur at this time, the self-boiled mixture may be omitted in many cases with reasonable safety. But during warm, rainy springs, especially in the South, the lime-sulphur mixture will doubtless be necessary in this application. In case the self-boiled lime-sulphur mixture is not used there should be added to each 50 gallons of water the milk of lime made from slaking 2 or 3 pounds of good stone lime, in order to counteract any caustic action of the arsenate of lead.

"Second application.— Two or three weeks later, or about one month after the falling of the petals, spray with the 8–8–50 self-boiled lime-sulphur mixture and 2 pounds of arsenate of lead.

"Third application.— About one month before the fruit ripens, spray with the 8–8–50 self-boiled lime-sulphur mixture, omitting the poison.

"For earlier maturing varieties of peaches, such as Waddell, Carman, and Hiley, the first two treatments outlined above will usually be sufficient but in very wet seasons badly rotting varieties would probably require three treatments. Late varieties, such as Smock and Salway, having a longer season, would not be thoroughly protected by three applications, but on account of the expense there is hesitation in recommending a fourth spraying. In view of the results obtained on midseason varieties, it seems likely that three treatments will ordinarily be sufficient for the late varieties."

CONTROL OF PEAR SCAB

Our experiments and observations on pear scab the past season strongly emphasize the importance of not allowing the scab fungus to get a foot-hold in the orchard, especially in case of the susceptible varieties, such as Duchess and Flemish Beauty. Pear scab, once well established on susceptible trees, is very hard to control when conditions are favorable for its development, as they were during the past season, 1910. This applies much more to pear than to apple scab. Apple scab can be controlled on the fruit almost entirely by the first season's treatment, although the orchard may never have been sprayed before. Why this difference? The apple scab fungus is carried over chiefly if not entirely by the winter stage which develops on the fallen leaves, producing a crop of spores which are shot into the air in early spring to infect the new leaves and fruit buds. It does not to any extent, at least, if ever, develop and hibernate on the twigs.

On the pear, on the other hand, the fungus grows abundantly on the twigs and once thus established, working under cover, it cannot be killed by the spray. These infected spots on the twigs will therefore continue to grow throughout the season constantly producing a crop of spores as a convenient source of infection for leaves and fruit.

Our experiments during the past season on pears were conducted in a block of Duchess that had not been thoroughly sprayed for several years and consequently the twigs were very abundantly infected with scab fungus. Many combinations as to time and number of applications were made with both bordeaux and lime-sulfur with lead arsenate added, as well as with several other preparations. Suffice it to say here that even where four or five applications were given, which prevented infec-

tion throughout the early summer effectively, almost every pear was scabby at picking time. Other orchards of the same variety near by, which had formerly been kept well sprayed and whose twigs were not abundantly scabbed, gave quite clean fruit from three applications. It seems clear, then, that the constant source of infection furnished by this abundant twig scab, due to previous neglect in this case, made almost constant spraying throughout the summer necessary.

Another important point demonstrated by this work is the action of early fungous infection on pedicles of fruit in preventing a good set. Although the set in the orchard mentioned was very poor there were six bushels of fruit gathered from the forty-eight trees which were properly sprayed before the blossoms opened and after they fell, while from 1720 trees sprayed (not thoroughly) only after the blossoms fell only 13 bushels were gathered,— 16 times as many per tree on the properly sprayed plat.

In regard to the time and number of applications necessary to control pear scab, it might be noted that it is stated by R. E. Smith ('05) of California that two applications before the blossoms open seem necessary in many cases in that state, making the first as the leaf buds are bursting, the second before the blossoms open. The first application does not seem to us to be important in this State, as shown in our experiments. The early infection was practically as well controlled where this application was omitted and but very slightly reduced where this, only, was given.

Table 9, constructed from counts made of fruit on the tree on June 2nd and 4th, gives an idea of the relative importance of the various applications in preventing early scab infection. It shows that the application before the blossoms open and all later applications were important, and the fact that practically all the pears later became scabby before picking time shows that still later spraying was necessary in this case. In reasonably clean orchards, however, applications Nos. 1, 2, and 3 were quite effective.

Lime-sulfur (commercial) was diluted 1–40 and with it 2 pounds of lead arsenate per 50 gallons was used. This caused rather objectionable foliage injury on Duchess but very little on Bartlett, Anjou, Clairgeau, and other varieties. Bordeaux 3–3–50 with the same amount of lead arsenate caused in this case rather more foliage injury than the lime-sulfur and considerably more russeting of fruit. The control of scab was about equal in each case.

('05) Smith, R. E. Pear Scab. Cal. Agr. Exp. Sta. Bul. 163:1–18. 1905.

TABLE 9.— RESULTS OF DIFFERENT TIMES OF APPLICATION WITH BORDEAUX AND LIME-SULFUR ON PEAR SCAB. COUNTS MADE JUNE 2 AND 4. PEARS ½ TO ¾ IN. IN DIAMETER.

APPLICATIONS*	Bordeaux, % scab	Lime-sulfur, % scab	Check, % scab
0	91.5	85.1	100
1	21.4	11.7	.....
2	94.5	93.3	.....
0, 1	18.9	8.0	.....
0, 1, 2	11.5	12.0	.....
0, 1, 2, 3	4.9	4.5	.....
1, 2	21.2	8.5	.....

* Application 0 = As leaf buds were bursting.
1 = A few days before blossoms opened; buds exposed.
2 = Blossoms about two-thirds fallen.
3 = Two weeks later.